DOCUMENT RESUME

ED 265 171 TM 850 654

AUTHOR van der Sanden, Johan M. M.; Schouten, Tony A.
TITLE Learner Strategies and Aptitude Treatment Interactions on Psychomotor Tasks in Technical Schools.
PUB DATE Mar 85
NOTE 23p.; Paper presented at the Annual Meeting of the American Educational Research Association (69th, Chicago, IL, March 31-April 4, 1985).
PUB TYPE Speeches/Conference Papers (150) -- Reports - Research/Technical (143)

EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS Aptitude Treatment Interaction; Cognitive Processes; *Cognitive Style; Factor Analysis; Field Dependence Independence; Foreign Countries; Learning Modalities; *Learning Strategies; Locus of Control; Manipulative Materials; *Mechanical Skills; *Perceptual Motor Learning; *Psychomotor Skills; Regression (Statistics); Secondary Education; Spatial Ability; Student Characteristics; *Trade and Industrial Education
IDENTIFIERS Netherlands

ABSTRACT

Research was performed in lower grade technical schools in the Netherlands to study complex psychomotor tasks requiring integration of several task-dependent skills. In two studies, students were observed performing metal work. They were assigned to instructional conditions of high, intermediate or low structure. Students in the high-structure condition had to perform the task according to a teacher-provided plan, which specified a list of actions students were required to follow. Students in the low-structure condition were given nothing but a design of the product, and they had to decide upon all necessary operations. On the average, high-ability students made better products in less time and used a relatively smaller part of that time for orienting activities than low-ability students. High-ability students performed worst under high-structure conditions, whereas low-ability students performed best under these conditions. A third study involved the performance of a wiring task. No instructions were given. Two strategies could be distinguished--a goal-directed strategy and a trial and error strategy. A tentative hypothesis involving a positive relation between spatial-technical ability and goal-directed strategy was derived. (LMC)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

Learner Strategies and Aptitude Treatment Interactions on Psychomotor Tasks in Technical Schools

Johan M.M. van der Sanden
Tilburg University
P.O. Box 90153
5000 LE Tilburg
The Netherlands

Johan M.M. van der Sanden
Tilburg University
The Netherlands

Tony A. Schouten
University of Technology Eindhoven
The Netherlands

ED265171

Précis

Three studies have been carried out in lower grade technical schools. In two studies students were observed performing metal work. They were randomly assigned to instructional conditions of high, intermediate or low structure. On the average high-ability students made better products in less time and used a relatively smaller part of that time for orienting activities than low-ability students. High-ability students performed worst when under 'high structure' instructions, whereas low-ability students performed best under these conditions.

To take a closer look at learner strategies another study was carried out. Students were observed performing a wiring task. No instructions were given. Two strategies could be distinguished i.e. a 'goal-directed' strategy and a 'trial-and-error' strategy.

Paper presented at the 1985 AERA Annual Meeting in Chicago

Not to be cited without permission of the authors

TM 850 654

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)
✓ This document has been reproduced as received from the person or organization originating it.
☐ Minor changes have been made to improve reproduction quality.
• Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY
J. van der Sanden
TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

BEST COPY AVAILABLE

Learner Strategies and Aptitude Treatment Interactions on Psychomotor tasks in Technical Schools

Johan M.M. van der Sanden
Tilburg University
P.O. Box 90153
5000 LE Tilburg
The Netherlands

Johan M.M. van der Sanden
Tilburg University
The Netherlands

Tony A. Schouten
University of Technology Eindhoven
The Netherlands

INTRODUCTION

The research project 'Psychomotor skills in technical schools' is carried out at Tilburg University and Eindhoven University of Technology.
Based on the ATI-paradigm (Cronbach & Snow,1977; De Klerk, 1983) the project's aim is to investigate the relations between learner characteristics, instructional and outcome variables on psychomotor tasks.
Psychomotor skills may take many forms, varying from relatively simple, elementary movements to highly complex movement sequences. Whether being performed automatically or with a great deal of attention, the major characteristic of motor activity seems to be the movements of various parts of the body. In studying psychomotor skills, however, it would be incorrect to restrict research to observable, physical movements, thereby losing sight of cognitive determinants of motor behavior. Several authors have taken this position. Newell (1978), for instance, stresses the dynamic relation between knowledge and action. Adams (1976) states that '...actually motor behavior is draped with more cognitive activity than most are willing to admit' (op.cit., p. 89). Singer (1980) discusses the role of cognitive processes in learning psychomotor skills.
In the research project 'Psychomotor skills in technical schools' we are primarily interested in rather complex psychomotor tasks requiring integration of several task-dependent part-skills and application of relevant knowledge. In performing metal work, for instance, students are required to study a design, to scribe a piece of metal, to choose suitable actions, to select appropriate tools, to determine the sequence of steps to be taken and to apply part-skills as filing, sawing and drilling. Such tasks are typical for the kind of practical work students in the upper grades of technical schools are engaged in.
Evidently, in performing this type of psychomotor task cognition plays a major role. Students are confronted with practical construction problems for which

they have to find a solution. It is not possible to arrive at a solution by resorting to an automatized sequence of actions, instead a balanced combination of thinking and doing is required. Elaborating this theme into a 'rational' task-analysis (Resnick, 1976), it is supposed that an efficient performance on this kind of psychomotor task entails the following processes (cf. Singer, 1978):

Goal-image formation: creating a mental image of the goals to be reached.
Analysis: translating the problem(s) into technical terms and considering the steps to be taken.
Planning: ordering the required activities in a plan of action.
Execution: performing the activities.
Evaluation: monitoring on-going performance and checking executed actions.

Depending on the performer's skillfulness and/or the nature of the task these processes may ask more or less conscious involvement (cf. Fitts and Posner, 1969) and may take more or less time.

One of the persistent problems in ATI-research is to find relevant combinations of task-, learner- and instruction variables. Trying to avoid haphazard combinations we inferred potentially relevant learner- and instruction variables from the above mentioned task-analysis.

Considering the emphasis on spatial and technical information processing, it was judged necessary to include measures of spatial visualization ability and/or spatial mechanical ability. Performing the tasks students have to form representations of the goals to be reached and have to monitor ongoing actions. This implies, among other things, constructing spatial representations from different perspectives (e.g. front views, side-views) and imagining what happens if a stimulus is moved from one position to another (e.g. imagining current-flow as a consequence of different switch-modes). In this respect Lohman and Kyllonen (1983) have distinguished transformations as 'mental movement' ('reflecting, rotating, folding, or simply imagining that a stimulus is moved from one position to another...') and 'construction or synthesis' ('...reorganizing the stimulus elements in a new way...') (op.cit., p. 112).

Cognitive style, especially field(in)dependence, seems to be another relevant learner characteristic. Having to act independently students are obliged to structure a rather complex task situation, not losing themselves in unnecessary details.

Of course, performing elementary psychomotor skills as sawing, filing and wiring entails precise and goal-directed movements of hands and fingers. So in our studies manual dexterity was included as a learner characteristic.

Along the same line one might consider prior familiarity with these elementary psychomotor skills an important, be it more transient learner characteristic.
Given the above mentioned task- and learner characteristics, which instructional variables might be brought into play?
Evidently, for successful performance on complex psychomotor tasks a systematic task approach is needed. Students have to assemble elementary mental operations like goal-image formation, analysis, planning and eveluation into goal-directed sequences and combinations, such an assembly representing a task specific strategy (cf. Posner & McLeod, 1982). Singer (1980) has distinguished externally imposed and self-initiated strategies. One way to confront students with an externally imposed strategy is to provide them with a structured task situation. Keeping Tobias' instructional support hypothesis in mind (Tobias, 1976), we varied task structure, thereby offering our students different amounts of support. In our view task strucure is high when:
a) Instructions bear upon all or most of the required mental operations.
b) Instructions are explicit.
c) Instructions are many.
d) Students are obliged to follow the instructions.
On the other hand, task structure is low when:
a) Instructions bear upon none or few of the required mental operations.
b) Instructions are rather abstract or vague.
c) Instructions are few.
d) Students are at liberty to follow the instructions.
This classification scheme concerining content (a), modality (b), quantity (c) and freedom (d) was used as a heuristic device in developing and characterizing instructional procedures.

In this paper we present data on two research questions:
1. Which amount of structure is benevolent for which type of student?
2. What kind of strategies are employed by students when under low structure conditions?

STUDY 1

Design and method

This study refers to the first of the two research questions mentioned above. Only immediate instructional effects were considered, making a distinction between two kinds of dependent variables, viz. process and product variables. To make process registrations possible students worked one at a time, their

performances being video-taped and observed by well-trained observers. Observations were focussed on two categories: orienting activities like studying the design, making a 'development', checking, making notes, asking for help, and executive activities like sawing, drilling and wiring. Process information was also obtained through interviews at task completion.
A product score was computed for each student's piece of work by rating it according to a specified list of criteria.
40 Third-year lower grade students of a technical school participated in this study. They had to construct a piece of metal work, viz. a soldering-iron holder. Several learner characteristics were involved in the study, among these: technical and spatial ability, cognitive style (fielddependence-fieldindependence) and manual dexterity. These characteristics were assessed by means of standardized tests. Besides a self-developed measure concerning familiarity with the executive actions was included.
Students were randomly assigned to one of two instructional conditions. Students in the high-structure condition had to perform the task according to a teacher-provided analysis and planning, specifying and sequencing a list of actions. They were obliged to follow this rather detailed list of instructions. Students in the low-structure condition were given nothing but a design of the product. They had to decide upon all necessary operations on their own.
On the average it took students 2 hours to complete the task.
Data were analyzed using multiple regression analysis (SPSS; Nie et al., 1975). Test scores were standardized. A condition vector was formed through effect-coding (Kerlinger & Pedhazur, 1973). Predictors were entered in a pre-established hierarchy: learner characterictics first, then the condition vector and last learner characteristic by condition interaction terms. To obtain un-standardized regression coefficients regression analyses were run for each condition separately. Main effects of instructional conditions were tested for significance by entering but the condition vector.

Results

In table 1 some descriptive statistics concerning aptitude measures and dependent variables are presented for the entire sample (N=40).

Table 1

Table 1 shows positive relationships between technical and spatial ability

and the quality of the products; total working time and number of pauses are negatively related to these product scores. Spatial ability has a negative relationship with total working time and number of pauses. Manual ability and fieldindependence are negatively related to respectively, total working time and intensity of reported cognitive processing.

Effects of high versus low structure are reported in table 2. As the table shows there are no instructional main effects.

Table 2

In tables 3 to 7 results of regression analyses concerning interactions between learner characteristics and instructional conditions are reported. Each table gives information on the amount of variance accounted for (% var), the F-value (F), the regression constant (a) and the regression slope (b). Table 3 bears upon the dependent variable PRODUCT, tables 4 to 7 bear upon the dependent process variables FCONS, FPAUSE, TMOTR and ICOG, respectively.

Tables 3 to 7

The interactions can be summarized as follows:

Under low structure (LS) product scores tend to increase with increases in manual ability, technical ability and fielindependence; under high structure (HS) increases in fieldindependence go together with slightly decreasing product scores; technical and spatial ability are not related to the product scores. As to the process variables it appears that observed or reported intensity of cognitive processing is negatively related to manual and technical ability, fieldindependence and familiarity under lowly structured instructions; under highly structured instructions there is no or a slightly positive relationship between these aptitudes and intensity of cognitive processing. Students with high familiarity scores spend most time on executive activities under low structure; for students with low familiarity scores, however, the opposite occurs: high structure makes them spend the most time on executive activities.

Schematic graphs, representing the above mentioned interactions are presented

in figure 1.

---

figure 1

STUDY 2

Design and method

In Study 1 only short-term effects of high and low structure were investigated. A second study was performed to investigate long-term retention and transfer effects. Besides a moderate structure condition was added.

180 Third-year lower grade students of 6 technical schools participated in this study. Performing a learning task (a piece of metal work) they were randomly assigned to instructional conditions of high, moderate or low structure. In the low-structure condition the learning task was not divided into subtasks; students were free to choose their own strategy; only the design of the product (half of a soldering-iron holder) was given to them. In the moderate-structure condition the task was subdivided into seven part-tasks, which had to be performed in a fixed order. So students were obliged to work following a rather rough teacher-provided analysis and planning. The same was true for the high-structure condition, be it that a much more detailed analysis and planning (17 subtasks) were given.

On the average it took students about 1½ hours to complete the learning task. Afterwards each student was given knowledge of results concerning the quality of the finished product. Three weeks later all students performed the same task (the other half of the soldering-iron holder) without any help or instructions, allowing retention effects to be examined. Again three weeks later all students made a transfer task, another piece of metal work (a screw-driver holder), calling on the same part skills with some additional problems. During task performance students were observed; having completed the tasks they were interviewed about their working method.

As in the first study several learner characteristics were involved. Aptitude scores were factoranalyzed (principal factors with orthogonal rotation). The first factor generated accounted for 35% of aptitude variance. All tests carrying on spatial or technical information processing were loading high on this factor, so it was named 'spatial-technical intelligence' (STI). For each student a factorscore on this factor was computed. Factorscores were used as a predictor in multiple regression analyses (SPSS; Niet et al, 1975).

Condition vectors were created through contrast-coding (Kerlinger & Pedhazur, 1973). Analyzing the data the same procedure as in Study 1 was followed. In this paper only data pertaining to the spatial-technical factor and the product scores are presented.

Results

In table 8 means and standarddeviations concerning the product scores are reported for the entire sample (N=180).

Table 8

Inspection of the mean product scores learns that students perform rather poorly, mean scores for the learning and transfer task being even lower than half the maximum score. The difference between mean retention and mean learning score is significant (T=-5.79;p=0.00), so there is a main retention effect. In table 9 mean product scores and standarddeviations are reported for each instructional condition separately.

Table 9

Regression analyses were run to test differences between all possible orthogonal contrasts, none of them being significant (see table 10).

Table 10

In table 11 results of regression analyses that were run to test for interaction effects are reported. Only the STI (spatial-technical intelligence) by HML (contrast of high with moderate and low structure) interaction term is considered here. Separately for learning, retention and transfer task the tabel gives information on the amount of variance accounted for (% var) by the interaction term, the F-value (F). the regression constant (a) and the regression slope (b).

Table 11

The significant interactions occurring at the retention and transfer tasks can be interpreted as follows: in the long run students scoring high on 'spatial-technical intelligence' perform best having learned under conditions of low or moderate structure. Students with low scores on 'spatial-technical intelligence', however, perform best after high structure.

STUDY 3

Design and method

To take a closer look at learner strategies a third study was performed. In this study 134 students made an electric alarm system according to a written description of its functioning. No further instructions were given, thus enabling students to execute the task following their own ('self-initiated'; Singer, 1980) strategy.
Like in the first two studies several student characteristics were assessed, among these spatial-technical ability and field(in)dependence.
Performing the task students were closely observed by trained observers, who's attention was focussed on orienting activities. A distinction was made between directed and undirected orienting activities. Examples of directed activities are: reading instructions, designing a wiring diagram and evaluating. These activities may be considered necessary preparations for the wirings to be performed. Activities like 'playing with the wiring components' or 'making a pause, apparently doing nothing' were classified as undirected.
To get a comprehensive view on learner strategies the observational data were factoranalyzed, using pricipal factoring with orthogonal rotations (SPSS; Niet et al, 1975). Factoranalyses were performed separately for relative time spent on the various orienting activities and on their frequencies.

Results

The results of the factoranalyses are presented in table 12.

Table 12

The first time-factor, named GOAL, accounts for 54 % of variance. Students scoring high on this factor spend relatively much time making a wiring diagram and lining out the circuit on the wiring board, and relatively little time on the undirected activities named above.

Students scoring high on the second time-factor, T-ORI, spend relatively much time on first orientations, e.g. skimming instructions and schema's, before undertaking any executive actions.

Undirected activities and (re)consulting schema's are loading high on the first frequency-factor, FREQ 1. Students scoring high on the second frequency-factor, FREQ 2, work relatively often on the wiring diagram. They often ask for help and frequently draw on their wiring board.

Students did not only differ in the way they approached the task, they also obtained different results. The wirings were marked in two ways by judging the technical quality of the connections and by counting the number of correct connections with regard to the functioning of the circuit.

An interesting question to be asked is whether students making a good product act differently from students making a bad product. For this purpose the group was divided into good, average and bad performers for both types of product scores. Table 13 shows mean scores on time- and frequency-factors for good and bad performers; average performers have been left out. In the same table students' mean scores on spatial-technical intelligence (a factor-score like in STUDY 2) and on total working time are displayed. The significance of between-groups' differences was determined by applying T-tests.

Table 13

Significant differences between good and bad performers occur on spatial-technical intelligence, total working time, the first time-factor (GOAL) and both frequency-factors. As may be expected good performers are more intelligent than bad performers. Good products are made in relatively little time. Compared with bad performers good performers score significantly higher on 'GOAL', indicating they spend relatively much time designing a wiring diagram; many bad performers did not (try to) make such a diagram at all. Good performers also spend much time lining out the circuit on the wiring board and little time on undirected activities. The differences between good and bad performers on the frequency-factors show that (too) much switching between activities does not benefit performance.

Based on the above reported data-analyses two learner strategies may be

defined according to their effectiveness. The first learner strategy, named the goal-directed strategy, is best characterized by high scores on 'GOAL'. Students approaching the task this way spend relatively much time preparing executive actions by designing diagrams and outlines. They waste little time on undirected activities.

The other learner strategy is named the trial-and-error strategy. Students show this working method when they often go from one activity to another without completing any of them. Directed and undirected activities alternate as if students cannot decide or do not know what to do. In interviews afterwards these students often reported that indeed they did not know where to start.

It is tentative now to hypothesize a positive relation between spatial-technical ability and the goal-directed strategy. However, no significant correlations were found between spatial-technical intelligence and scores on any of the process factors. An effective working method does not seem to be the privilege of more intelligent students!!

GENERAL DISCUSSION

Performing complex psychomotor tasks lays a heavy cognitive load on the performer. Like every problem solver the learner has to go through a series of operations while executing the task. In the introduction several potentially relevant cognitive operations were stated. Especially goal-image formation, analysis and planning seem to be conditional for successful execution of a complex psychomotor task.

The third study has given some evidence as to student differences in performing these mental operations. So the trial-and-error strategy described in this study may have evolved because students are having problems:

a) Converting the written description of the alarm system into a mental image of the final product.
b) Translating the image into an operaional model and analyzing this model into electric components and its corresponding symbols (making a schema).
c) Deciding which steps are to be taken.
d) Planning the order of to be performed activities.

Considering the problems that might arise it seem obvious to try to support students' cognitive processes with external representations of required internal operations. In this respect Salomon (1979) has claimed that '...the less a learner is capable of producing the requisite internal representations, whether images, propositions, summary statements or graphlike models, the more will an external code that is isomorphic with that requisite internal representation improve comprehension and learning' (op.cit., p. 137).

In the first two experiments students were given support by offering them

highly structured instructions. Students were obliged to perform the tasks according to a teacher-provided, rather detailed analysis and planning. These instructions were contrasted with lowly structured conditions in which students were given nothing but a design of the product or a less detailed analysis and planning.

In both studies these instructional conditions had no short-term or long-term main effects on the quality of the products. However, some interesting aptitude-treatment interactions were found. Students scoring low on technical and spatial ability, fieldindependence and manual ability performed best when given highly structured instructions. High-ability students, however, performed worst under these instructions. Under high structure low-ability students' observed or reported intensity of cognitive processing was lowest. It appears that the instructions provide a working scheme or a strategy they cannot develop themselves, relieving them from the information-processing burden. When obliged to act on their own (in lowly structured conditions) intensity of cognitive processing was found to be increasing.

For high-ability students intensity of cognitive processing was highest under conditions of high structure. The predetermined structure appears to interfere with their own way of organizing activities.

Interestingly, in the second study interactions did not occur at the learning task, but at the retention and transfer tasks. Evidently, differential instructional effects as found in this study can be lasting, even impeding high-ability students' returning to their own preferred ways of coping with psychomotor tasks!!

For cognitive tasks interference-effects as found in the first two studies were also reported by Mayer (1976), Tobias (1976), Tobias & Ingber (1976). Snow (1977, 1980) and Tobias (1982) have reviewed the various studies. Snow (1977) summarizes the research findings as follows: '... treatments based on simplified models, algorithms, direct rules to follow, etc. may be detrimental to High G students, even while they help Low G students. This is a special case of the general hypothesis ... about the locus of the information-processing burden, student or treatment. It is an especially interesting case because it implies negative effects on High G students. Some kind of interference phenomenon, operating between what the model tries to help students do and what students would ordinarily do on their own, seems to be responsible. But the source of this interference cannot be pinned down more exactly at present' (op.cit., p. 75). According to Snow (op.cit.) it is uncertain whether the source of the negative effects of instruction on high-ability students is to be ascribed to cognitive, motivational or other factors. Tobias (1982) offers a motivational explanation: 'Providing instructional

support to students who have substantial experience with a subject may do little to increase achievement, and may actually be counterproductive. That is, additional support typically requires students to spend more time and effort on material that they can master in less time-consuming ways. The extra support might then cause enough boredom, carelessness, or fatigue to reduce achievement compared to a 'learner' instructional strategy' (op. cit., p. 7).

Realizing that it is not motivating to have to perform a task according to alien procedures, we suggest that interference is primarily a cognitive phenomenon. Learning and information-processing are regulated by the interplay of internal and external control mechanisms (cf. Singer's distinction between externally imposed ans self-initiated strategies; Singer, 1980). External mechanisms can only be effective if they correspond with the cognitive style and abilities of the learner. When strategies are externally imposed (e.g. in high-structure conditions) 'mismatches' are likely to occur. High-ability students' increase in intensity of cognitive processing under conditions of high-structure may be regarded a consequence of suboptimal tuning of external to internal control mechanisms.

In our view the studies reported in this paper have shown that it can be a fruitful approach to study students' cognitive activities in performing (psychomotor) tasks. Tobias (1982) has taken a similar position, stating that...'It is not useful merely to vary different instructional methods and monitor achievement or other outcomes. In addition, the types of cognitive processing activities that occur while students are working on instructional material should be studied' (op. cit., p. 8).

In the third study reported here we tried to characterize students' cognitive processing activities into two distinct strategies. One wonders what might happen if students' prevalent strategies (instead of abilities) are used as predictors of psychomotor performance under conditions of differing instructional structure. Our present research efforts are directed at answering this and related research questions.

References

ADAMS, J.A., Issues for a closed-loop theory of motor learning. In: G.E. Stelmach (ed.), Motor control. Issues and trends. New York: Academic Press, 1976.

CRONBACH, L.J. & SNOW, R.E., Aptitudes and instructional methods: a handbook for research on interactions. New York: Irvington, 1977.

DE KLERK, L.F.W., Onderwijspsychologie. Deventer: Van Loghum Slaterus, 1983.

FITTS, P.M. & POSNER, M.I., Human performance. Belmont Calif.: Brooks Cole, 1969.

LOHMAN, D.F. & KYLLONEN, P.C., Individual differences in solution strategy on spatial tasks. In: R.F. Dillon & R.R. Schmeck (eds.), Individual differences in cognition. Volume I. New York: Academic Press, 1983.

MAYER, R.E., Different problem-solving competencies established in learning computer programming with and without meaningful models. Journal of Educational Psychology, 1975, 67, 725-734.

NEWELL, K.M., Some issues on action plans. In: G.E. Stelmach (ed.), Information processing in motor control and learning. New York: Academic Press, 1978.

NIE, H.N., HULL, C.H., JENKINS, J.G., STEINBRENNER, K. & BENT, D.H., Statistical Package for the Social Sciences (SPSS). New York: Mc-Graw-Hill, 1975.

POSNER, M.I. & MCLEOD, P., Information processing models - In search of elementary operations. Annual Review of Psychology, 1982, 33, 477-514.

RESNICK, L.B., Task analysis in instructional design: some cases from mathematics. In: D. Klahr (Ed.), Cognition and instruction. New York: Erlbaum, 1976.

SALOMON, G., Media and symbol systems as related to cognition and learning. Journal of Educational Psychology, 1979, 71, 131-148.

SINGER, R.N., Motor skills and learning strategies. In: H.F. O'Neil (Ed.), Learning strategies I. New York: Academic Press, 1978.

SINGER, R.N., Motor behavior and the role of cognitive processes and learner strategies. In: G.E. Stelmach & J. Requin (Eds.), Tutorials on motor behavior. Amsterdam: North Holland Publ. Comp., 1980.

SNOW, R.E., Research on aptitude for learning: a progress report. In: L.S. Shulman (Ed.), Review of Research in Education IV. Itasca: Peacock, 1977.

SNOW, R.E., Aptitude processes. In: R.E. Snow, P.A. Federico & W.E. Montague (Eds.), Aptitude, learning and instruction, volume I. Hillsdale N.J.: Lawrence Erlbaum Ass., 1980.

TOBIAS, S., Achievement treatment interactions. Review of Educational Research, 1976, 46, 61-74.

TOBIAS, S. & Ingber, T., Achievement-treatment interactions in programmed instruction. Journal of Educational Psychology, 1976, 68, 43-47.

TOBIAS, S., When do instructional methods make a difference? Educational Researcher, 1982, 11, 4-9.

BEST COPY AVAILABLE

Table 1: Means (M), standarddeviations (SD) and Pearson-correlations concerning aptitudes and dependent variables (N=40)

VARIABLE	M	SD	CORRELATION COEFFICIENTS									
			1	2	3	4	5	6	7	8	9	10	11
1. MANUAL	14.78	4.47	-	.46***	.47***	.12	.11	.31	-.08	-.26	.17	-.25	-.37**
2. FIELD	11.63	4.00		-	.32**	.18	.13	.29	-.11	-.28	.38**	-.35**	-.19
3. TECH	40.39	9.73			-	.38**	.48***	.44***	-.24	-.15	.04	.02	-.35**
4. SPATIAL	60.60	13.59				-	.09	.40***	-.22	-.56***	.41***	.10	-.39**
5. FAM	2.44	.70					-	.30	.03	-.09	.05	.07	-.42***
6. PRODUCT	17.45	6.20						-	-.22	-.38**	.33**	-.08	-.33**
7. FCONS	5.45	4.60							-	.39**	-.03	.28	.35**
8. FPAUSE	29.08	14.50								-	-.47***	.20	.61***
9. TMOTR	.42	.07									-	-.24	-.23
10. ICOG	.00	.58										-	.22
11. TTOT	131.50	32.50											-

** $p \leq .05$ *** $p \leq .01$

Definitions of abbreviations:

MANUAL: manual ability
FIELD: field(in)dependence
TECH: technical ability
SPATIAL: spatial ability
FAM: familiarity
PRODUCT: product score for soldering-iron holder
FCONS: frequency of consulting the design
FPAUSE: frequency of registered (thinking) pauses
TMOTR: relative time spent on executive activities
ICOG: intensity of cognitive processing as reported in interview
TTOT: total working time (measured in minutes)

Table 2: Variance accounted for (% var) by high versus low structure with respect to the dependent variables PRODUCT, FCONS, FPAUSE, TMOTR, ICOG and TTOT; F-values (F), means (M) and standarddeviations (SD) by condition (df=38)

DEPENDENT VARIABLE	CONDITION-VECTOR		HIGH STRUCTURE		LOW STRUCTURE	
	% var	F	M	SD	M	SD
PRODUCT	2.40	.94	16.50	6.29	18.40	6.12
FCONS	6.97	2.85	4.25	3.71	6.65	5.16
FPAUSE	.00	.00	29.00	13.32	29.15	15.95
TMOTR	4.82	1.92	.41	.06	.44	.07
ICOG	1.90	.74	.08	.52	-.08	.64
TTOT	.16	.06	132.80	35.00	130.20	30.30

See table 1 for definitions of abbreviations

Table 3: Interactions of aptitudes and instructional conditions on PRODUCT scores (df=36)

INTERACTION TERM	% var	F	CONDITION	a	b
MANUAL X C	8.60	3.84*	LS	17.91	3.24
			HS	16.41	-.57
FIELD X C	17.26	8.35***	LS	16.37	4.70
			HS	16.05	-1.04
TECH X C	6.19	3.02*	LS	17.82	3.69
			HS	16.55	.31

Table 4: Interactions of aptitudes and instructional conditions on FCONS scores (df=36)

INTERACTION TERM	% var	F	CONDITION	a	b
MANUAL X C	14.27	6.65**	LS	6.94	-1.93
			HS	4.51	1.71
FIELD X C	14.91	7.48***	LS	8.11	-3.38
			HS	4.50	.58
TECH X C	10.41	5.06**	LS	7.02	-2.37
			HS	4.39	.88

Table 5: Interactions of aptitudes and instructional conditions on FPAUSE scores (df=36)

INTERACTION TERM	% var	F	CONDITION	a	b
FIELD X C	15.20	7.32***	LS	34.22	-11.75
			HS	29.36	.84

Table 6: Interactions of aptitudes and instructional conditions on TMOTR scores (df=36)

INTERACTION TERM	% var	F	CONDITION	a	b
FAM X C	10.16	4.30**	LS	.43	.02
			HS	.40	-.02

BEST COPY AVAILABLE

Table 7: Interactions of aptitudes and instructional conditions on ICOG scores (df=36)

INTERACTION TERM	% var	F	CONDITION	a	b
FAM X C	11.36	4.75**	LS	-.07	-.12
			HS	.11	.28

* p≤.10 ** p≤.05 *** p≤.01

Definitions of abbreviations (tables 3 to 7):
LS: low structure HS: high structure
See table 1 for definitions of other abbreviations

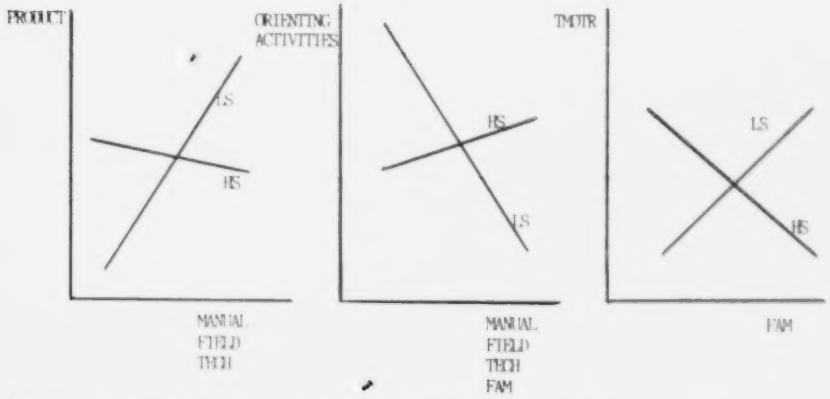

Figure 1: schematic representation of significant interactions

Table 8: Means (M) and standarddeviations (SD) concerning product scores (N=180)

VARIABLE	M	SD
PRODUCTL	38.17	20.95
PRODUCTR	47.03	12.49
PRODUCTT	25.88	9.59

Definitions of abbreviations:
PRODUCTL: product score for learning task 1)
PRODUCTR: product score for retention task 1)
PRODUCTT: product score for transfer task 2)
1): maximum score 90 2): maximum score 68

Table 9: Mean product scores (M) and standarddeviations (SD) by instructional condition (N=60 for each condition)

PRODUCTSCORE	PRODUCTL			PRODUCTR			PRODUCTT		
CONDITION	HS	MS	LS	HS	MS	LS	HS	MS	LS
M	36.33	36.73	41.45	45.02	48.23	47.83	26.98	24.63	26.02
SD	23.17	20.09	19.35	14.14	11.70	11.41	8.56	9.75	10.39

Definitions of abbreviations: HS: high structure; MS: moderate structure
LS: low structure; see table 8 for definitions of other abbreviations

Table 10: Variance accounted for (% var) by the condition vectors and F-values (F) with respect to product scores (df=177)

VARIABLE	CONDITION VECTOR											
	HL		MHL		HM		LHM		ML		HML	
	% var	F	% var	F	% var	F	% var	F	% var	F	% var	F
PRODUCTL	1.00	1.79	.24	.42	.01	.01	1.23	2.21	.85	1.52	.39	.69
PRODUCTR	.85	1.53	.47	.84	1.11	2.00	.21	.37	.02	.03	1.30	2.44
PRODUCTT	.17	.30	.85	1.51	1.01	1.80	.01	.02	.35	.62	.67	1.19

Definition of abbreviations:
HL contrasts high structure with low structure
MHL contrasts moderate structure with high and low structure
HM contrasts high structure with moderate structure
LHM contrasts low structure with high and moderate structure
ML contrasts moderate structure with low structure
HML contrasts high structure with moderate and low structure

Table 11: Interactions of spatial-technical intelligence (STI) and high versus moderate and low structure (HML) on product scores (df=174)

INTERACTION	PRODUCTL					PRODUCTR					PRODUCTT				
TERM	% var	F	C	a	b	% var	F	C	a	b	% var	F	C	a	b
STI X HML	.80	.10				1.51	3.30*				3.35	7.28***			
			HS	36.17	8.38			HS	44.95	3.46			HS	26.95	1.44
			MS	36.26	9.04			MS	47.84	7.60			MS	24.37	5.13
			LS	42.07	8.60			LS	48.30	6.48			LS	26.44	5.92

* p≤.10 *** p≤.01

Table 12a: Results of factor analysis on relative time spent on orienting activities

PROCESS VARIABLE	GOAL	TOR1	CONS
1 First orientations	.12	.71	-.03
2 Scribing	.40	-.07	-.11
3 Playing with components	-.52	-.18	-.14
4 Designing wiring diagram	.65	.12	-.12
5 Consulting schema's	-.02	.05	.59
6 'Doing nothing'	-.45	-.03	.06
7 Evaluating (part)products	.00	-.09	.21
8 Asking for help	.20	.12	-.32
VARIANCE ACCOUNTED FOR	54 %	27 %	19 %

Table 12b: Results of factor analysis on frequencies of orienting activities

PROCESS VARIABLE	FREQ 1	FREQ 2
1	.28	.27
2	.27	.39
3	.50	-.02
4	-.04	.48
5	.69	.21
6	.64	.14
7	.39	-.10
8	-.03	.48
VARIANCE ACCOUNTED FOR	72 %	28 %

See text for definitions of abbreviations

BEST COPY AVAILABLE

Table 13: Mean scores (M) of good and bad performers on process factors, spatial-technical intelligence and total working time (N=47 for each group)

VARIABLE	Technical quality of connections			Quantity of correct connections		
	M good performers	M bad performers	T	M good performers	M bad performers	T
GOAL	.19	-.25	2.66**	.11	-.19	1.81
TOR1	-.02	-.06	.27	-.08	-.04	-.29
CONS	.11	-.07	1.21	-.03	-.07	.25
FREQ 1	-.04	.04	-.47	-.26	.10	-2.11**
FREQ 2	-.19	.03	-1.63	-.19	.16	-2.41**
SPATIAL-TECHNICAL INTELLIGENCE	.41	-.36	4.11**	.13	-.28	2.12*
TOTAL WORKING TIME 1)	9708.	10657	-2.52*	9733	10618	-4.34**

* $p \leq .05$ ** $p \leq .01$ 1) time measured in seconds

See text for definitions of abbreviations

BEST COPY AVAILABLE

BEST COPY AVAILABLE

Table 7: Interactions of aptitudes and instructional conditions on ICOG scores (df=36)

INTERACTION TERM	% var	F	CONDITION	a	b
FAM X C	11.36	4.75**	LS	-.07	-.12
			HS	.11	.28

* p≤.10 ** p≤.05 *** p≤.01

Definitions of abbreviations (tables 3 to 7):
LS: low structure HS: high structure
See table 1 for definitions of other abbreviations

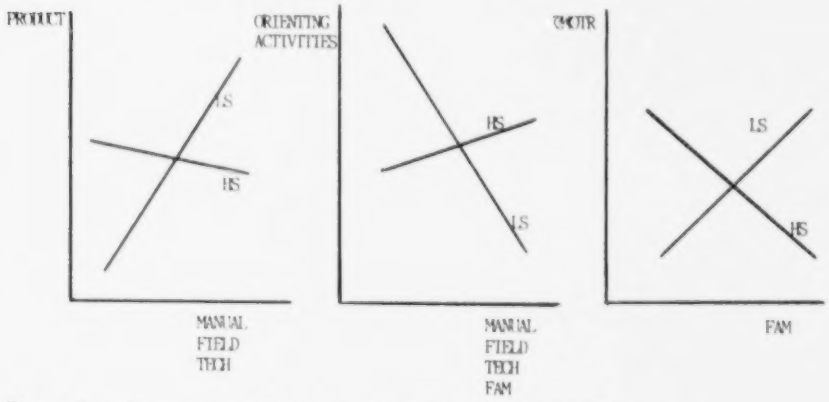

Figure 1: schematic representation of significant interactions

Table 8: Means (M) and standarddeviations (SD) concerning product scores (N=180)

VARIABLE	M	SD
PRODUCTL	38.17	20.95
PRODUCTR	47.03	12.49
PRODUCTT	25.88	9.59

Definitions of abbreviations:
PRODUCTL: product score for learning task 1)
PRODUCTR: product score for retention task 1)
PRODUCTT: product score for transfer task 2)
1): maximum score 90 2): maximum score 68

Table 9: Mean product scores (M) and standarddeviations (SD) by instructional condition (N=60 for each condition)

PRODUCTSCORE	PRODUCTL			PRODUCTR			PRODUCTT		
CONDITION	HS	MS	LS	HS	MS	LS	HS	MS	LS
M	36.33	36.73	41.45	45.02	48.23	47.83	26.98	24.63	26.02
SD	23.17	20.09	19.35	14.14	11.70	11.41	8.56	9.75	10.39

Definitions of abbreviations: HS: high structure; MS: moderate structure
LS: low structure; see table 8 for definitions of other abbreviations

Table 10: Variance accounted for (% var) by the condition vectors and F-values (F) with respect to product scores (df=177)

VARIABLE	CONDITION VECTOR											
	HL		MHL		HM		LHM		ML		HML	
	% var	F	% var	F	% var	F	% var	F	% var	F	% var	F
PRODUCTL	1.00	1.79	.24	.42	.01	.01	1.23	2.21	.85	1.52	.39	.69
PRODUCTR	.85	1.53	.47	.84	1.11	2.00	.21	.37	.02	.03	1.30	2.34
PRODUCTT	.17	.30	.85	1.51	1.01	1.80	.01	.02	.35	.62	.67	1.19

Definition of abbreviations:
HL contrasts high structure with low structure
MHL contrasts moderate structure with high and low structure
HM contrasts high structure with moderate structure
LHM contrasts low structure with high and moderate structure
ML contrasts moderate structure with low structure
HML contrasts high structure with moderate and low structure

Table 11: Interactions of spatial-technical intelligence (STI) and high versus moderate and low structure (HML) on product scores (df=174)

INTERACTION TERM	PRODUCTL					PRODUCTR					PRODUCTT				
	% var	F	C	a	b	% var	F	C	a	b	% var	F	C	a	b
STI X HML	.80	.10				1.51	3.30*				3.35	7.26***			
			HS	36.17	8.38			HS	44.95	3.46			HS	26.95	1.44
			MS	36.26	9.04			MS	47.84	7.60			MS	24.37	5.13
			LS	42.07	8.60			LS	48.30	6.48			LS	26.44	5.92

* p≤.10 *** p≤.01

Table 12a: Results of factor analysis on relative time spent on orienting activities

PROCESS VARIABLE	GOAL	TORI	CONS
1 First orientations	.12	.71	-.03
2 Scribing	.40	-.07	-.11
3 Playing with components	-.52	-.18	-.14
4 Designing wiring diagram	.65	.12	-.12
5 Consulting schema's	-.02	.05	.59
6 'Doing nothing'	-.45	-.03	.06
7 Evaluating (part)products	.00	-.09	.21
8 Asking for help	.20	.12	-.32
VARIANCE ACCOUNTED FOR	54 %	27 %	19 %

Table 12b: Results of factor analysis on frequencies of orienting activities

PROCESS VARIABLE	FREQ 1	FREQ 2
1	.28	.27
2	.27	.39
3	.50	-.02
4	-.04	.48
5	.69	.21
6	.64	.14
7	.39	-.10
8	-.03	.48
VARIANCE ACCOUNTED FOR	72 %	28 %

See text for definitions of abbreviations

Table 13: Mean scores (M) of good and bad performers on process factors, spatial-technical intelligence and total working time (N=47 for each group)

VARIABLE	Technical quality of connections			Quantity of correct connections		
	M good performers	M bad performers	T	M good performers	M bad performers	T
GOAL	.19	-.25	2.66**	.11	-.19	1.81
TORI	-.02	-.06	.27	-.08	-.04	-.29
CONS	.11	-.07	1.21	-.03	-.07	.25
FREQ 1	-.04	.04	-.47	-.26	.10	-2.11**
FREQ 2	-.19	.03	-1.63	-.19	.16	-2.41**
SPATIAL-TECHNICAL INTELLIGENCE	.41	-.36	4.11**	.13	-.28	2.12*
TOTAL WORKING TIME 1)	9708	10657	-2.52*	9733	10618	-4.34**

* $p \leq .05$ ** $p \leq .01$ 1) time measured in seconds

See text for definitions of abbreviations

BEST COPY AVAILABLE